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PENSOFT

New and noteworthy Hypnales (Bryophyta) records from the Nuluhon Trusmadi Forest Reserve in Borneo

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Abstract
Four Hypnales mosses from three pleurocarpous families are recorded in Borneo for the first time. They are *Neonoguchia auriculata* (Copp. *ex* Thér.) S.H. Lin (Meteoriaceae), *Oxyrrhynchium bergmaniae* (E.B. Bartram) Huttunen & Ignatov (Brachytheciaceae), *Thamnobryum latifolium* (Bosch & Sande Lac.) Nieuwl. (Neckeraceae), and *Trachycladiella sparsa* (Mitt.) M. Menzel (Meteoriaceae). The specimens were collected from Nuluhon Trusmadi Forest Reserve in Sabah, Malaysian Borneo. Descriptions and illustrations of the four species as well as notes on their distribution and distinguishing characteristics are provided.

Keywords
Malaysian Borneo, moss, Mount Trus Madi, Sabah

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Introduction

The order Hypnales contains about 4,200 species, which represents one-third of all known moss species (Goffinet et al. 2009). Many species of this order do not show specificity with respect to their substrates and habitats. So far, 25 families, 102 genera, and more than 200 species of Hypnales have been recorded in Borneo (Suleiman et al. 2006). However, a relatively large area in Borneo is yet to be explored extensively by bryologists, and an increase in field surveys will likely result in newly recorded species. An example in Borneo of such an unexplored area is the Nuluhon Trusmadi Forest Reserve (NTFR). The NFTR is located in the central part of Sabah, between latitude 05°17′16″–05°47′60″N and between longitude 116°20′04″–116°38′14″E (Fig. 1). The nearest towns are Tambunan and Keningau, about 40 km west and 70 km southwest from the reserve's center, respectively.

The topography of the NTFR comprises mainly mountainous landscapes at the northern part and hilly landscapes towards the southern part (Sabah Forestry Department 2014). The highest peak of the NTFR is Mount Trus Madi (2,642 m a.s.l.), which is the second tallest mountain in Borneo after Mount Kinabalu.

Natural vegetation found in the NTFR comprises of upper montane forest (2,000–2,500 m a.s.l.), occupying an area of 2,219.66 ha; lower montane forest (1,500–2,000 m a.s.l.), which is the dominant forest type in the NTFR (41,970.98 ha); upland hill dipterocarp forest (600–1,499 m a.s.l.), covering an area of 32,127.40 ha; the summit scrub including the peak of Mount Trus Madi, occupying an area of 29.90 ha; and a small fragment of mixed lowland dipterocarp forest (up to 599 m a.s.l.) of about 637.62 ha, located adjacent to the border of the forest reserve.

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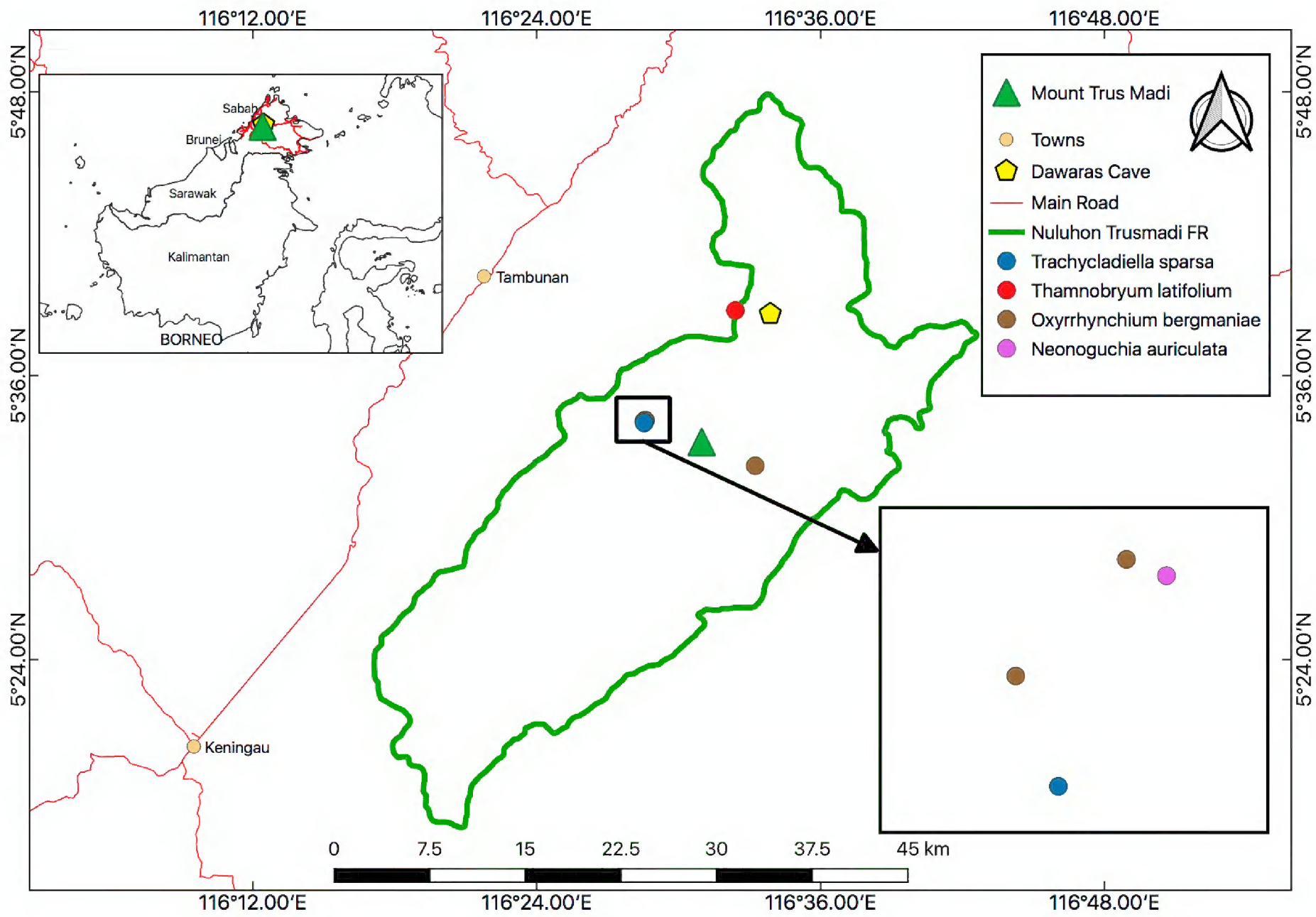

Figure 1. Map of Nuluhon Trusmadi Forest Reserve showing the collection sites of four new records of mosses from Borneo (insert: map of Borneo).

Here we report four newly recorded species of Hypnales mosses for Borneo collected from the NTFR.

Methods

Botanical surveys were carried out along the trails of Wayaan Mannan and Wayaan Kaingaran to the summit of Mount Trus Madi in the NTFR. This was done as part of an effort to study the moss flora on the reserve. All substrata of mosses were searched carefully during sampling, especially the four main substrata, namely tree trunks, soil, rocks, and logs. When possible, areas within 5 m on each side of the trails were explored. Specimens were collected from 600 m to 2,642 m above sea level. The collecting method used was adapted from O'Shea (1989). Voucher specimens were deposited in Sandakan Herbarium of Sabah Forestry Department (SAN) and duplicates were sent to BORNEENSIS Herbarium of Universiti Malaysia Sabah (BORH).

Previous collections deposited in BORH and SAN were also examined, including that of Sir Gary A. Shea in 1971, and a few collections of mosses by researchers from Sabah Forestry Department in 1995. The largest collection was contributed by Monica Suleiman in 1996, 2001, 2002, and 2008. Most of her collections were from Wayaan Kaingaran.

The identification of these samples was done using relevant literature (Bartram 1939; Noguchi 1976; Gangulee 1980; Tan and Noguchi 1984; Ignatov et al. 1999; Tan and Jia 1999; Akiyama et al. 2001). Nomenclature of mosses follows Goffinet et al. (2009) and Goffinet and Buck (2010) with some modification, while genera and species were arranged in alphabetical order. The status of new records for Borneo was evaluated using relevant literature (Suleiman and Edward 2002; Suleiman et al. 2003, 2006, 2009, 2011a, 2011b, 2017a, 2017b; Suleiman and Akiyama 2004, 2007; Andi and Suleiman 2005; Higuchi et al. 2008; Muller and Pursell 2009; Ellis et al. 2010, 2016a, 2016b; Mohamed et al. 2010; Tan and Mohamed 2013; Sugau and Andi 2014; Andi et al. 2015; Chua and Suleiman 2015; Suleiman and Jotan 2015; Suleiman and Rimi 2016; Suleiman and Andi 2019). Photographs of diagnostic characters of the new records were taken using Olympus Digital Camera DP72 at the Phytochemistry Laboratory of Forest Research Centre (FRC), Sabah Forestry Department, Malaysia.

The global geographical distributions of these new records were reviewed based on relevant references (e.g. Pant and Tewari 1984; Redfearn and Wu 1986; Lin 1988; Tan and Buck 1989; Tan and Iwatsuki 1991; Tan and Jia 1999; Telenius 2016; MNHN 2020; Ramirez et al. 2020) as well as online databases (GBIF 2020; Tropicos 2020). The distributions of these new records were mapped by using https://mapchart.net/world.html and Microsoft Photo Editor.

Results

Four newly recorded species of mosses from three pleurocarpous families of the order Hypnales are added to the moss flora of Borneo. The descriptions and illustrations of the four species, identification and notes on their global distributions are provided below.

***Neonoguchia auriculata* (Copp. *ex* Thér.) S.H. Lin.** (Meteoriaceae)
Figure 2

New record. BORNEO • Sabah, Tambunan District, Nuluhon Trusmadi Forest Reserve, Wayaan Kaingaran, 05° 34′07″ N, 116°28′36″E, alt. 1390 m, on tree bark, 27 Sep. 1996, M. Suleiman 264c (SAN, BORH).

Identification. Plants rigid, yellowish-green to brown. Secondary stems elongate, ca 15 cm long, with leaves ca 4 mm wide, laxly branched. Branches widely spreading, simple and complanately leaved, obtuse. Stem leaves erect spreading when dry, 3.5–4.0 mm × 0.8–1.5 mm, ovate-oblong, long acuminate and flexuose, plicate, at basal corner largely auriculate, the acumen subpiliferous; costa very slender, reaching 2/3 the leaf-length; margin erect, often undulate below. Median lamina cells linear-hexagonal, with acute ends, 45–60 µm × 6.0–8.5 µm, unipapillose, thin-walled; mid-basal cells thickened and subporose. Branch leaves smaller than the stem leaves, much broader, 2.5 mm × 1.0 mm. Sporophyte not seen.

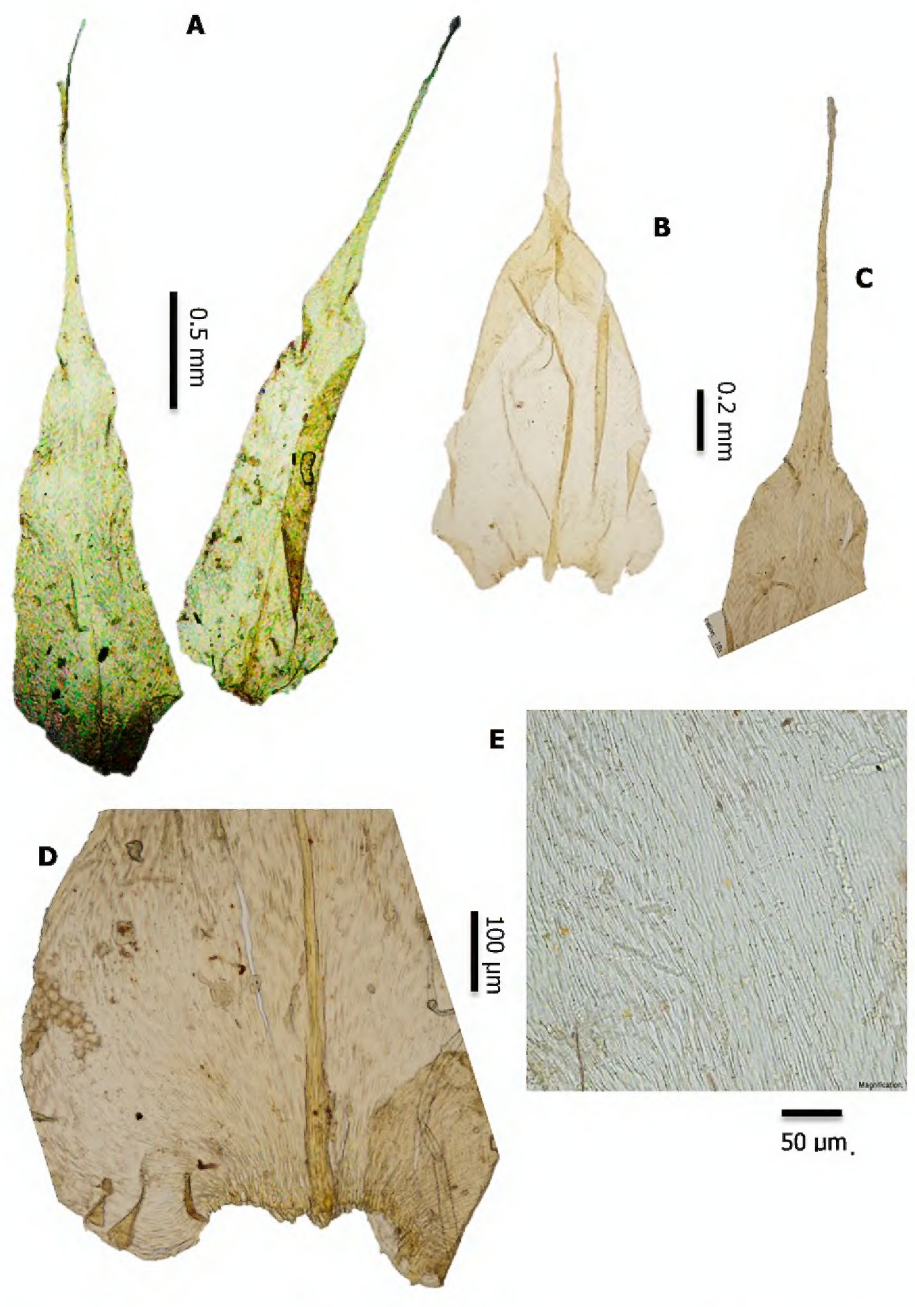

Figure 2. *Neonoguchia auriculata*. **A.** Stem leaves (SL). **B.** Branch leaf (BL). **C.** SL apex. **D.** SL auriculate base. **E.** Lamina cells. All based on M. Suleiman 264(c).

***Oxyrrhynchium bergmaniae* (E.B. Bartram) Huttunen & Ignatov** (Brachytheciaceae)
Figure 3

New records. BORNEO • Sabah, Tambunan District, Nuluhon Trusmadi Forest Reserve, Wayaan Kaingaran, 05°34′03″N, 116°28′31″E, alt. 1370 m, on fallen branch by a stream, in partially shaded area, 25 Oct. 2001, M. Suleiman 675; 05°34′07″N, 116°28′35″E, alt. 1350 m, on treelet trunk, along old logging roads, in partially shaded area, 30 Apr. 2008, M. Suleiman 2732; Keningau District, about 6 km from Kg. Sinua, Wayaan Mannan, 05° 32′11″N, 116°33′14″E, alt. 1372 m, on a large boulder on the bank of a mountain stream, 5 Nov. 1971, GA Shea 2196.

Identification. Plants yellowish-green to golden-yellow, pendulous, remotely pinnate, up to 9 cm, moderately densely foliate, usually subjulaceous, rarely imperfectly complanate. Leaves erecto-patent to patent when dry, spreading when moist, broadly ovate, 1.5–2.0 mm × 0.9–1.2 mm, apex sharply acuminate, costa stout, ending 1/5 below apex, margin sharply dentate. Lamina cells linear, 66–78 µm × 5–7 µm, prorate, thin-walled. Sporophyte not seen.

***Thamnobryum latifolium* (Bosch & Sande Lac.) Nieuwl.** (Neckeraceae)
Figure 4

New record. BORNEO • Sabah, Tambunan District, Nuluhon Trusmadi Forest Reserve, Dawaras cave, 05°38′44″ N, 116°32′24″ E, alt. 1490 m, on limestones by a stream, in open to partially shaded areas, 29 Mar. 2002,

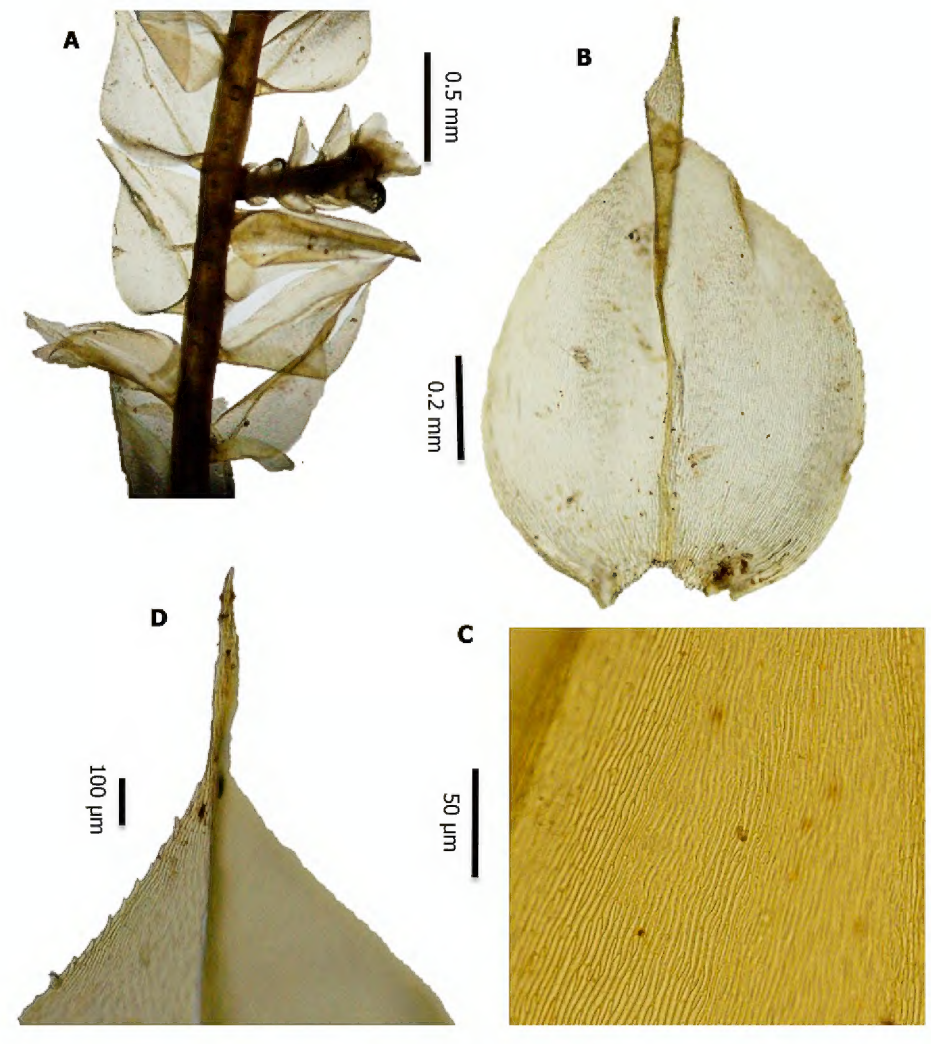

Figure 3. *Oxyrrhynchium bergmaniae*. **A.** Plant. **B.** Leaves. **C.** Lamina cells. **D.** Leaf apex. All based on M. Suleiman 2732.

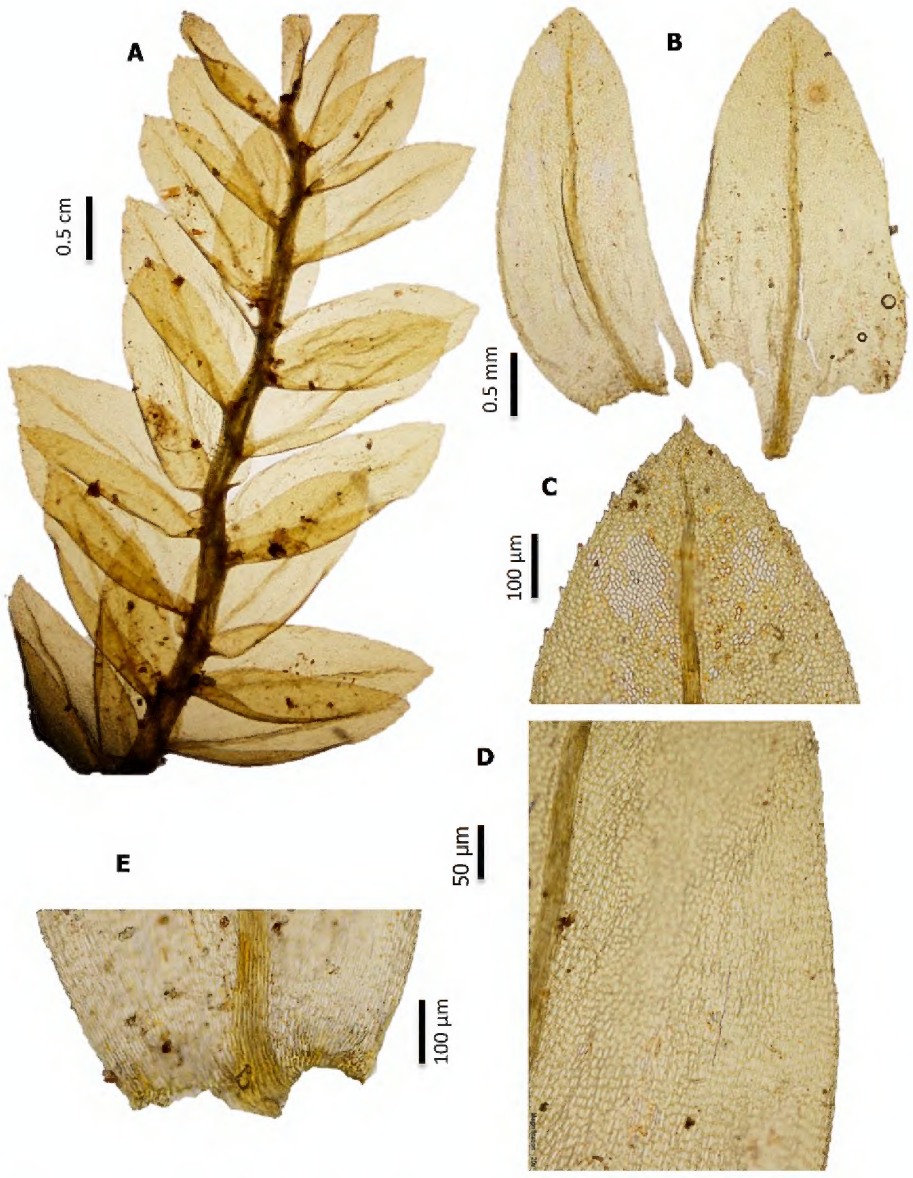

Figure 4. *Thamnobryum latifolium*. **A.** Plant. **B.** Leaves. **C.** Leaf apex. **D.** Lamina cells. **E.** Leaf base. All based on M. Suleiman 768 and 777.

M. Suleiman 768; M. Suleiman 777 (SAN, BORH).

Identification. Plants robust, dull green, dendroid in habit; secondary stems erect, 6–8 cm high, simple and woody below, irregularly bipinnate above; branches flat, widely spreading, tapering at tips. Stipe leaves small, distant, laxly spreading, gradually larger upward. Stem leaves erect-spreading, biplicate when dry, broadly ovate, abruptly contracted to a short, acute point, 2.3–2.8 mm × 1.1–1.5 mm, broadly inflexed on one side below, coarsely and irregularly serrate toward apex; costa stout, ending just below apex, with a few spines on the back. Lamina cells oval-hexagonal, 20.4 µm × 7.4 µm, smooth, marginal cells smaller at midleaf, gradually becoming linear towards base, porose. Sporophyte not seen.

***Trachycladiella sparsa* (Mitt.) M. Menzel**
(Meteoriaceae)
Figure 5

New record. BORNEO: Sabah, Tambunan District, Nuluhon Trusmadi Forest Reserve, Wayaan Kaingaran, 05°34′00″N, 116°28′34″E, alt. 1341 m, on tree trunks along road side, in open area, 28 Oct. 2001, M. Suleiman 702 (SAN, BORH).

Identification. Plants yellowish-green, stem rather loosely leaved, terete. Stem leaves slightly complanate, broadly ovate-oblong, rapidly contracted to a piliferous apex, 0.5–0.6 mm × 0.2 mm, the basal angles slightly decurrent; margin undulate, crenulate or serrulate throughout; costa slender, reaching mid-leaf, smooth, pellucid. Lamina cells obscure, walls thick, papillose on lateral walls, 30–40 µm × 4–5 µm, marginal cells papillose.

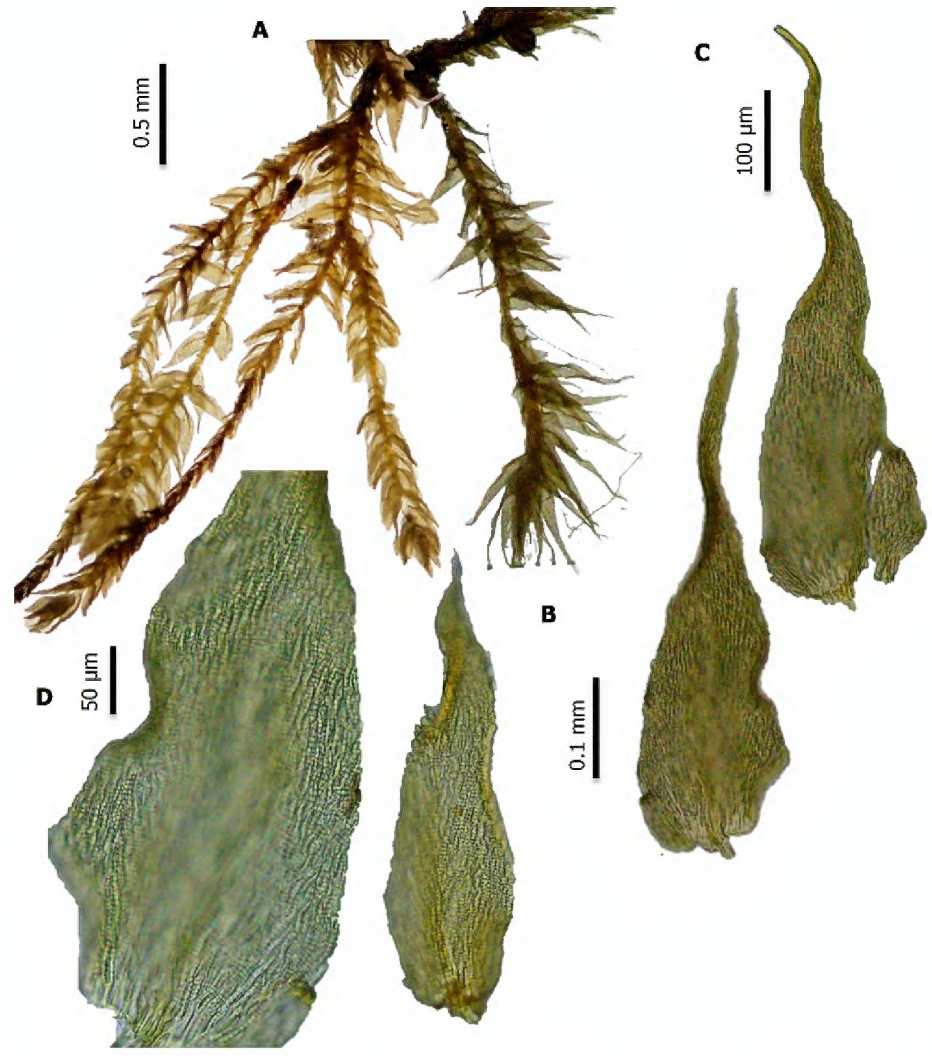

Figure 5. *Trachycladiella sparsa*. **A.** Plant branches. **B.** Leaves. **C.** Leaf apex, extreme tip broken. **D.** Leaf cells. All based on M. Suleiman 702.

Branch leaves terete, smaller than stem leaves, 0.3 mm × 0.1 mm. Sporophyte not seen.

Discussion

Borneo is a huge island and only a small fraction of its land mass has been bryologically explored. Thus, the probability of finding newly recorded as well as undescribed species of bryophytes is still high (Akiyama and Suleiman 2015; Andi et al. 2015; Chua and Suleiman 2015; Ellis et al. 2015, 2016a, 2016b, 2018, 2019; Zhu et al. 2017; Suleiman and Andi 2019; Suleiman et al. 2019). With the four new additions of pleurocarpous mosses, Borneo now has 773 species and infraspecific taxa of mosses.

Among the four newly recorded species of mosses reported here, *Neonoguchia auriculata* is the rarest species in Borneo with only a single collection known. It was found intermingled with two other species of mosses, *Actinodontium rhaphidostegum* (Müll.Hal.) Bosch & Sande Lac. (Pilothricaceae) and *Meiothecium jagorii* (Müll.Hal.) Broth. (Sematophyllaceae). Noguchi (1976) questioned the placement of this species in the genus *Aerobryopsis* due to its large auriculate leaf base and thickened cell walls of the leaves, and Lin (1998) later classified it as *Neonoguchia auriculata*. The phylogenetic affinities of *Neonoguchia* are still uncertain, but it is closely related to *Meteoriopsis* (Huttunen and Quandt 2007). *Neonoguchia auriculata* cannot be mistaken for *Meteoriopsis reclinata* (Müll. Hal.) M. Fleisch., which is the only species of *Meteoriopsis* in Borneo (Menzel 1992), on account of its strongly recurved and squarrose

branch leaves. *Neonoguchia auriculata* is a monotypic species and this is the first record of this species from the Malesian region. This species was previously known only in China and Taiwan, south to Myanmar and Bhutan (Fig. 6).

Oxyrrhynchium bergmaniae is similar to the more widespread *O. vagans* (A. Jaeger) Ignatov & Huttunen due to their broadly ovate leaves with sharply acuminate apex and sharply dentate margin. However, *O. bergmaniae* is much larger and golden-yellow. *Oxyrrhynchium bergmaniae* was previously thought to be endemic to Papua-New Guinea (Bartram 1960; Ignatov et al. 1999; Tan 2000) (Fig. 7), and Borneo is now the second locality of this species in the world. This species is fairly common in the NTRF and was found on various habitats in secondary forests and along old logging roads.

Figure 6. Global distribution map of *Neonoguchia auriculata* (yellow star = new record, red pentagon = previous records). The size of the pentagon is solely for descriptive purposes.

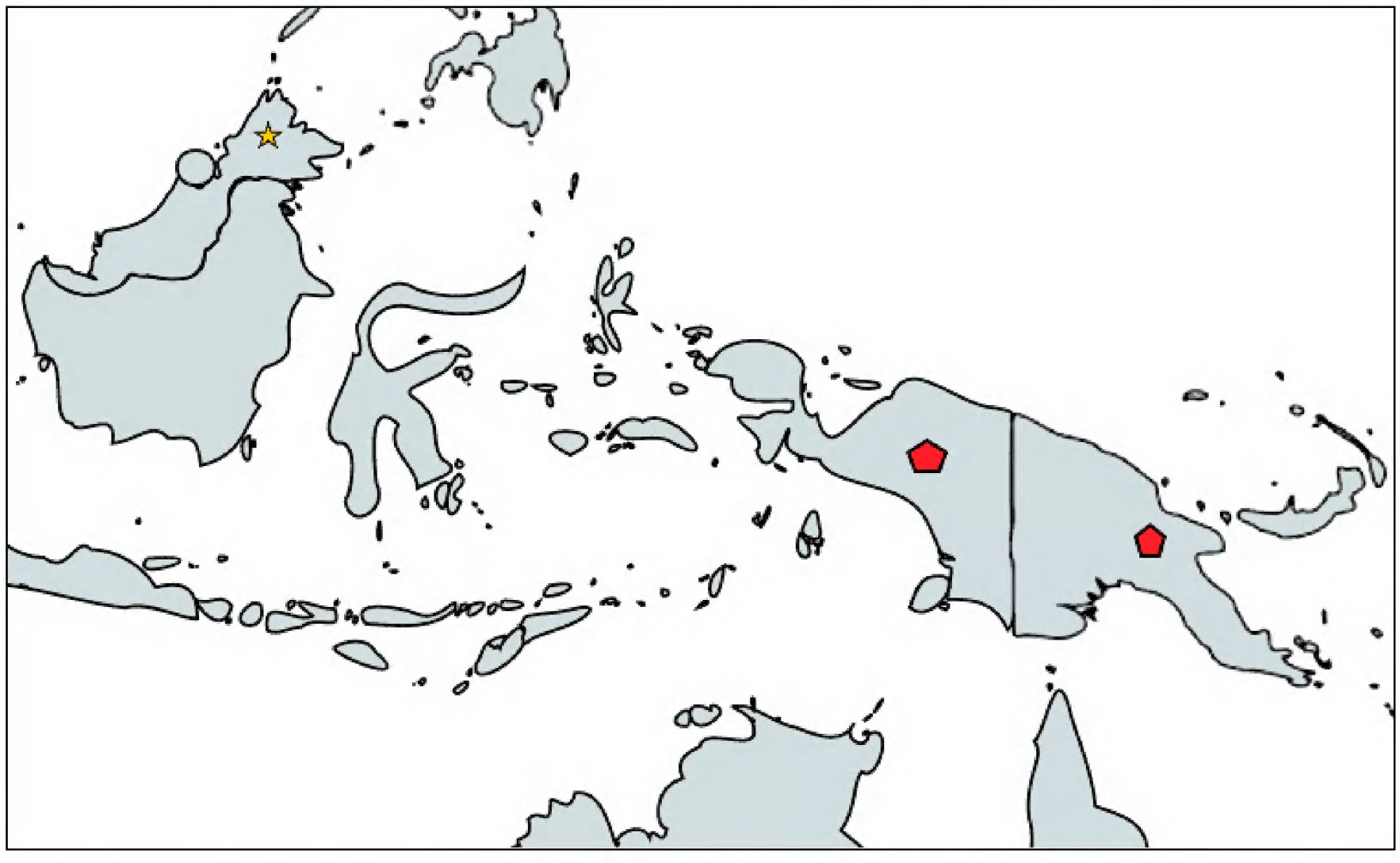

Figure 7. Global distribution map of *Oxyrrhynchium bergmaniae* (yellow star = new record, red pentagon = previous records). The size of the pentagon is solely for descriptive purposes.

The specimen of *Thamnobryum latifolium* was found at a limestone cave in a very remote lowland area of the NTFR. Limestone habitats harbor many interesting species of bryophytes and should be given emphasis by bryologists. The coarsely and irregularly toothed leaf apex, separate this species from the four other *Thamnobryum* species recorded in Borneo (Suleiman et al. 2017a). It is also characterized by its complanate stems and branches and short or isodiametric upper leaf cells. This species is distributed in Australia, China, India, Java, Maluku, Nepal, New Caledonia, New Zealand, the Philippines, Sumatra, and Taiwan (Fig. 8). Thus, its presence in Borneo was predicted.

There are only two known species of *Trachycladiella*, namely *T. aurea* and *T. sparsa*. These species have obscure lamina cells and the papillae are densely arranged on the longitudinal walls, which distinguishes them from *Floribundaria* species. *Floribundaria* can be distinguished from *T. aurea* by its large, sharp marginal teeth and by having all marginal cells papillose. The specimen from NTFR is quite small but all other characters are conform to the species (Noguchi 1976; Redfearn and Wu 1986; Tan and Iwatsuki 1991). *Trachycladiella sparsa* was previously recorded from Bhutan, China, Myanmar, Nepal, the Philippines, and Thailand (Fig. 9). Its occurrence in Borneo is evidence of its disjunct distribution from the Himalayas and northern Indochina.

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Authors' Contributions

The authors equally contributed to this article. The authors have declared that no competing interests exist.

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Figure 8. Global distribution map of *Thamnobryum latifolium* (yellow star = new record, red pentagon = previous records). The size of the pentagon is solely for descriptive purposes.

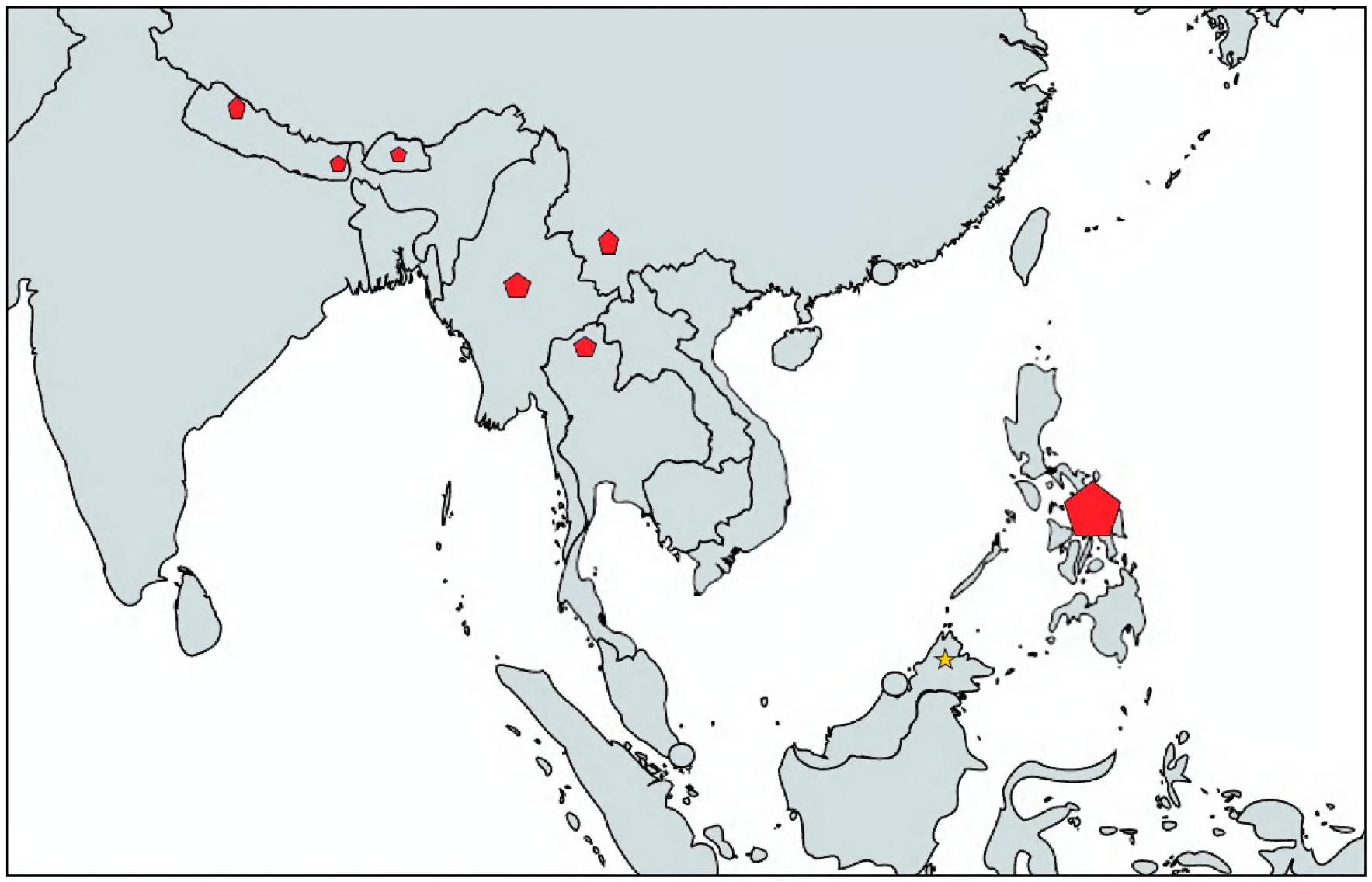

Figure 9. Global distribution map of *Trachycladiella sparsa* (yellow star = new record, red pentagon = previous records). The size of the pentagon is solely for descriptive purposes.

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